

2012

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McCarthy, B. (2012) 'The effects of logging and fragmentation on bird diversity', The Plymouth Student Scientist, 5(2), p. 558-568.

<http://hdl.handle.net/10026.1/14000>

The Plymouth Student Scientist
University of Plymouth

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The effects of logging and fragmentation on bird diversity

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Abstract

Deforestation and forest degradation is occurring globally at an alarming rate. The annual net loss of forest cover has been reduced in the past decade through sustainable forest management and conservation measures. Despite this, the remaining forest is becoming increasingly degraded with the total area of primary forest declining. Avian diversity has been shown to decline in degraded and fragmented forests due to logging activities. In this review the impacts of logging on avian communities are assessed by comparing diversity between primary forest and degraded secondary forest, industrial plantations and forest fragment sizes. The major organisations and current initiatives that are involved with reducing the impacts of logging are discussed, which may help to mitigate the threats to avian diversity. The detrimental effects of logging activities are starting to be reduced globally which may limit the decline in avian diversity. Nonetheless many sensitive species reliant on undisturbed forest are still under threat. This highlights the importance of protecting the remaining primary forests from logging activities.

Introduction

Forest covers over 4 billion hectares (ha) or 31% of the global land surface (FAO 2010). During the 1990's 16 million ha (mha) of forest per year was lost due to deforestation largely through land conversion, timber extraction and natural events such as fire and drought. In the last decade this has been reduced to 13 mha per year and afforestation (tree planting in non-forest areas), reforestation (re-planting) and natural regeneration has reduced the net loss by over 37% to -5.2 mha per year (FAO 2011). Reforestation by replanting harvested trees may result in no net loss of forest area but the ecosystem services and conservation value of the resulting forest will decline at least in the short term (FAO 2010).

Deforestation can occur by harvesting trees for solid wood products such as timber primarily for construction and also furniture as well as pulp and paper and for fuel as charcoal. Hardwoods are usually used for timber such as Dipterocarps in Asia and softwoods such as pine are used for pulp and paper. Deforested land can then be cleared for agriculture including crops, pasture and plantations (Blaser *et al* 2011). With a growing global population estimated to reach 9 billion in 2050 the demands and competition for forest products and land use for food production, urbanisation and biofuels will increase (Smith *et al* 2010). Simulation models confirm that the rate of deforestation is correlated to human population growth. At the current rate of deforestation it may take only 400 years for no forests to remain (Burchett & Burchett 2011).

Forests provide a variety of ecosystem services such as maintaining soil quality and structure, removing pollutants before entering water sources, conservation of flora and fauna and providing valuable carbon sequestration (Burchett & Burchett 2011). The value of the ecosystem services that tropical forests provide globally is estimated to be over US\$ 11 trillion a year. In the first five years of the new millennium 20% of tropical humid forests were logged which has affected ecosystem services and biodiversity (Sasaki *et al* 2011). Deforestation negatively impacts already threatened species with 89% of bird, 83% of mammal and 91% of plant threatened species being affected (Sasaki *et al* 2011).

Primary tropical forests can store more carbon than any terrestrial ecosystem (CBD 2011). Carbon is stored in living trees and vegetation, roots, and dead matter such as soil and litter. When deforestation or forest degradation occurs, carbon (in the form of carbon dioxide) and greenhouse gasses are released back into the atmosphere. Approximately 20% of greenhouse gas emissions in the last 20 years are due to deforestation of tropical forests (Houghton, 2005). Primary forests however sequester low amounts of carbon from the atmosphere, but instead act as a store or 'carbon pool'. Regenerating or new planted forests sequester carbon at a fast rate as the forest grows (Blaser *et al* 2011), so both primary and growing forests play a significant role in climate change mitigation.

Between 2000 and 2005 approximately 1.4% of humid tropical forests globally were deforested and the up to half of the remaining biome had tree cover of 50% or less (Asner *et al* 2009). However approximately 1.2% of humid tropical forests are in some stage of long term regeneration (over 10 years). Although this figure may appear promising this secondary regrowth of forests was mainly in disadvantaged

areas for agriculture such as uplands and mountainous regions which may only be important to certain species. Satellite observations and current literature were reviewed by Asner *et al* (2009) which highlighted the extent that logging has to forest disturbance. Mapping showed that over 90% more of forest area in the Brazilian Amazon displayed disturbance than deforested areas alone. Areas that had been subjected to logging were also had a 400% increased probability of deforestation compared to undisturbed forest.

Deforestation can have devastating effects on an ecosystem and so can the process of selective timber extraction. Mechanical processes destroy seedlings, compact soil and cause soil erosion. Reduced tree cover causes flooding events and waste and debris created from extraction enters water sources which can clog streams (Rachmatika 2005). Access to logging sites requires access routes for machinery and transport of timber. The effects of access routes can be significant to an ecosystem. Roads and paths fragment forests, create easy access for hunting and increase the chances of the remaining forest patches to be further logged (Pinard *et al* 2000). An example of how damaging access routes can be is in the logged forests of Queensland, Australia. Roads accounted for over 20% of the total deforestation (Crome *et al* 1996).

Logging Effects on Avian Diversity

Out of any of the animal taxa in forests, more is known about birds due to large amount of research especially in the tropics (Barlow *et al* 2007). Investigating how birds are affected by the changing landscape due to logging may help discover the implications for biodiversity as a whole in these important ecosystems.

Secondary forests are increasing in area worldwide through natural regeneration of abandoned agriculture land, plantations for industry or biofuel and managed reforestation for conservation and carbon sequestration. The true use of these landscapes in the short and long term for biodiversity is largely unknown (Barlow *et al* 2007).

Industrial tree plantations can provide a habitat for many species of birds. A study of mangium (*Acacia mangium*) plantations in Malaysian Borneo by Styring *et al* (2011) displayed that this fast growing tree species provides a habitat for a growing level of biodiversity as it ages. In the study various ages of plantations were surveyed to determine bird diversity and richness. Small sized species of insectivorous, nectarivorous and frugivorous birds that are common in native forest were also common in older plantations though large and rare species were rarely observed. Species richness was higher in plantations with highest canopy height (Styring *et al.*, 2011). Palm oil plantations provide a less suitable habitat for biodiversity compared to industrial tree plantations as their undergrowth is managed to a higher degree. By studying the community succession in industrial tree plantations it provides insight of how secondary forest growth can benefit biodiversity

Recent research carried out by Barlow *et al.* (2007) compared large primary, secondary and industrial eucalyptus plantations in north-east Brazilian Amazonia. Both secondary and plantation forests appeared to have poor foraging resources throughout the year for seed eating and frugivorous canopy birds. Species richness was significantly higher in primary forest which correlated to food availability.

Species richness decreased from older to younger secondary forest and then plantation. Secondary forest that also had natural re-growth 14-19 years after clear-felling showed significantly less bird diversity than primary forest (Barlow *et al* 2007). This shows that even after a significant amount of time forests may not provide a suitable habitat for specialist species and perhaps lack particular niches and microhabitats or that succession occurs at a slow rate. The study concludes that although secondary and plantation forests do not provide a suitable habitat for all species occurring in primary forest, they may provide dispersal routes over a short distance and are important for creating corridors between primary forests. Additionally degraded forests that have been selectively logged and allowed to regenerate provide greater value than planted forests and conservation efforts should be made to prioritise these habitats (Barlow *et al* 2007).

Plantation forests were also shown to have low bird diversity by Marsden *et al* (2001) who concluded only generalist species are able to use this habitat and secondary fragments have limited value but are still important to conserve for a number of species. Invertebrates have also shown to have low levels of species richness in plantations including ants (Suguituru *et al* 2011) and butterflies (Barlow *et al* 2008). Low levels of invertebrates may result in fewer insectivorous bird species due to a lack of food resources.

Many studies however have shown that secondary and degraded forests still can maintain relatively high levels of biodiversity. The effects of logging on 14 species of woodpecker were assessed in lowland tropical forests in West Kalimantan, Indonesian Borneo. Almost all lowland forests have been impacted by logging in the Sunda region of SE Asia. Woodpecker species richness showed little variation across forests with different intensities of logging disturbance but biomass and density was reduced by up to 61% and 41% respectively in logged forests (Lammertink 2004). Further evidence is provided in Costa Rica where bird diversity was shown to be higher in young degraded forest than older regenerated forest in two studies (Blake & Loiselle 1991, 2001). Also in Sulawesi secondary forests contained 82% of the bird diversity as in primary forest (Sodhi *et al* 2005). This may be due to sampling methods such as size and length of study as well as observational methods used, the proximity to primary forest and dispersal capabilities of species in each region.

Forest Fragmentation and Edge Effects

The forested wetlands of the Mississippi Alluvial Valley have been reduced to 24% of its historical size. The remaining forest has been fragmented into over 38,000 mainly small patches. Birds in forest patches have increased predation and nest parasitism due to a high edge to forest area ratio. Birds have also been negatively affected through competition, human disturbance and isolation causing reduced genetic diversity (Twedt *et al* 2004). Support models have been developed that show if forest restoration is targeted to increase the forest core area it will benefit biodiversity by providing a buffer from many of the threats to bird diversity (Twedt *et al* 2004). This highlights the importance of planning and targeting areas that will provide the most benefit to biodiversity.

As well as the impact that edge effects have on birds, such as nest parasitism and increased predators, there are also physical negative effects to the environment.

Forest litter structure, moisture and in turn litter dwelling invertebrates are affected 200m into the forest from the edge. Tree mortality is higher 500m into the forest and increased fire incidence occurs 1000m into forests. Therefore a circular shape forest would need to be over 314 ha to contain an area buffered from edge effects (Anjos *et al* 2011).

In West Africa forest habitats are highly fragmented. In the semi-deciduous forest region of Ghana Beier *et al* (2001) conducted bird surveys to determine whether forest structure including patch size, isolation and forest density had an influence on species richness and diversity of birds. Species richness increased with patch area size and large patches (>1000 ha.) contained comparable diversity to the diversity in the collective number of small patches. 25% of species were not found in small patches (3-11 ha.) and were therefore area sensitive. The results show the importance of large forest patches for conserving many sensitive species of birds but also show that small patches are of value to generalist species.

The forests of Madagascar are a biodiversity hotspot and contain a high proportion of endemic species. These forests have undergone severe and rapid deforestation due to logging and burning for agriculture (Myers *et al* 2000). Of the different forests in Madagascar the littoral forests are under the highest threat. This ecosystem occurs on the eastern coast in a now fragmented strip between sand and alluvium (Ganzhorn *et al* 2001). Watson *et al* 2004 showed that bird species richness increased with forest patch size in this region and of the area sensitive species the majority required areas of over 20 ha and some species needed a minimum of 150 ha. Both forest dependent canopy insectivorous and frugivorous species were the most affected by small habitat size. The recommendations of this study were that littoral forest patches over 200 ha should be protected as they supported the highest level of biodiversity. 55% of all forest-dependent species in Madagascar were found in this habitat type and only approximately 30% of forest-dependent species were likely to occur in a small patch landscape alone (Watson *et al* 2004). Larger patch sizes contain more resources such as food and breeding sites and have a smaller edge-area ratio which may reduce nest-parasitism and predation and are of more importance for conservation.

A meta-analysis by Lampila *et al* (2005) was conducted to determine the effects of habitat fragmentation on bird demographics mainly in boreal and temperate forests worldwide. Both residents and migrants were affected by fragmentation at similar levels. Breeding success reduced in species that nested on the ground or in shrubs or trees compared to those nesting in cavities in more fragmented habitats. This is likely to be due to increased predation. Nest parasitism and nest predation significantly increased with level of fragmentation and pairing success was the most affected (Lampila *et al* 2005). Pairing success was expected to be due to dispersal capabilities or female mate choice where females are selecting males from less fragmented forest habitats. Clutch size and fledgling condition were not affected by level of habitat fragmentation which suggests that even in a fragmented habitat, sufficient resources are available for certain species (Lampila *et al* 2005).

A 19 year study by Berry *et al* (2010) provided conflicting evidence that a regenerating logged forest that had lost over 50% above ground biomass was of high conservation value. Surveying over 2500 species from 11 taxa, logged forest

flora had higher species richness than primary forest and over 90% of fauna from primary forest was observed in logged forest. Regenerating degraded forests can be an important habitat for biodiversity. Conversely Newmark (2006) showed that insectivorous terrestrial birds were affected most significantly by low and moderate forest disturbance due to logging in Tanzania. Growth rates of common species did not show a significant increase during a 16 year period of regeneration. This highlights that although many studies may show increases in species richness or diversity over time they may not take into account individual species or feeding guilds.

A possible factor in conflicting research was made evident in a review by Swift and Hannon (2010). They investigated whether population declines occur linearly with the rate of habitat loss or whether after a certain level of loss they decline at a faster rate. This point is the 'critical threshold'. Most evidence supported a critical threshold level of 70-90% habitat loss but for specific taxa this was significantly less such as moths it was 50-60% and amphibians was 40-45% habitat loss. Species may therefore exist for some time in fragmented environments until the loss of habitat becomes too much for species to survive. Also small fragmented forest patches that may support high levels of biodiversity are more likely to have local extinctions as they are more prone to stochastic events such as drought or fire and are not stable. Additionally species that had a high abundance before fragmentation are likely to persist for a longer period in fragmented forest than those at low abundances as they are likely to have less inbreeding and negative allele effects (Anjos *et al* 2011). These factors therefore need to be taken into consideration when investigating the value of fragmented and degraded logged forests.

Mitigation of Logging Effects

Since the year 2000 there have been major advances in forest management and conservation with 76 countries improving their forest policy and now just less than 75% of global forests are included in national forest programmes (FAO 2011).

Reduced impact logging (RIL) systems have been developed in several countries. These systems have been developed to reduce the detrimental effects of logging by using improved harvesting techniques (Meijaard 2005). A pilot programme was initiated in Sabah, Malaysia by the Innoprise Corporation Sdn Bhd in 1996. A 1400 ha trial resulted in a 50% reduction in forest damage with 10-15% increase in costs (Marsh *et al* 1996).

RIL guidelines have since then been developed. In 1996 the Food and Agriculture Association (FAO) created the FAO Code of Practice for Forest Harvesting (Dykstra & Heinrich 1996) which has further been extended by the Centre for International Forestry Research (CIFOR) to be country specific such as for Indonesia (Elias *et al* 2001). RIL guidelines ensure best practice before, during and after logging. Prior to harvesting extensive tree mapping, tree inventories and road trails are planned to minimise disturbance, erosion and protect water quality and special conservation sites and endangered species are accounted for. Trees are harvested and transported to trails with minimal ground compaction and disturbance and a post-harvest assessment is conducted (Dykstra & Heinrich 1996; Meijaard 2005; Elias *et al* 2001).

If access routes are planned more effectively using RIL guidelines then forest disturbance can be minimised (Pinard & Putz 1996; Pinard *et al* 2000). Reduced impact logging has been displayed to be effective in Sabah, Malaysia where road area was reduced from 17% - 6% therefore reducing deforestation (Pinard *et al* 2000).

There are several organisations involved with forest management and conservation. The International Tropical Timber Organisation (ITTO) develops international policy and supports sustainable forest management and conservation of tropical forests worldwide. The majority of the world's tropical forests are in 65 countries of which 33 are ITTO member countries which in total have 1.42 billion ha of the 1.66 billion ha tropical forest cover (Blaser *et al* 2011). The ITTO is also promoting countries to create Permanent Forest Estates (PFE) which are areas of natural or planted forest that have permanent tree cover. These areas therefore maintain ecosystem services and have conservation value. Within PFE the areas can be designated protected or non-protected. Protected areas are not harvested of resources (Blaser *et al* 2011).

Sustainable forest management is a practice adopted by the FAO and ITTO and is where forests are maintained to produce products such as timber but are managed so that they still provide ecosystem services and are economically sustainable. This can be achieved through tree planting when forests are cleared or partially logged (Burchett & Burchett 2011). Forests that are sustainably managed for timber production will in time produce no net positive or negative impact on emissions (Blaser *et al* 2011).

Other important schemes such as Reducing Emissions from Deforestation and Forest Degradation (REDD+) which is a global initiative being negotiated by the United National Framework Convention on Climate Change (UNFCCC). This initiative involves paying compensation to developing countries for reducing carbon emissions. This will involve participating countries protecting and restoring forest areas, sustainable forest management and improving carbon stocks through enrichment planting (Phelps *et al* 2010). Although this initiative was set up to reduce climate change it benefits biodiversity through protection and restoration of forests.

Evaluation

Deforestation and forest degradation due to logging is still occurring at a fast rate. Although this may have reduced in the last decade, with a finite amount of primary forest existing (57% in Brazil alone) this is of great concern to conservation of forest species. With an increasing global population and the demand for forest resources and land raising (Smith *et al* 2010) the outlook may look bleak. Forests do however provide invaluable ecosystem services such as providing clean water with 75% of freshwater coming from watersheds purified by forested areas (CBD 2010). Forests ability to sequester and store more carbon than any other terrestrial ecosystem (CBD 2011) makes them vital for climate change mitigation.

Forest ecosystems are required for the majority of terrestrial flora and fauna. Conservation initiatives may protect and improve a proportion of forests but it may be likely that the policy and initiatives such as REDD+ (Phelps *et al* 2010) that are set up to mainly protect human interests in services and carbon emissions may protect more forest area. To sustain the demands for forest products sustainable forest

management practices allows deforested areas to be replanted for future use (Blaser *et al* 2011). RIL guidelines work to reduce the negative effects of logging to the environment and to biodiversity (Meijaard 2005). Many other schemes such as sustainable forestry certification programmes including the Rainforest Alliance Smartwood scheme encourage ethically sourced produce (Auld *et al* 2008). Policy is being improved in most countries around the world but this still needs to increase to protect primary and older regenerating forests.

The majority of research has suggested that biodiversity and species richness in secondary, degraded, fragmented and plantation landscapes is at much lower level than primary forest. Fragmented landscapes can affect species dispersal and genetic diversity which in turn can lead to inbreeding and reduced ability to adapt to the changing landscape and ultimately extinction (Ewers & Didham 2006). It may take up to 100 years for secondary forests to retain all of the biodiversity and complexity of a virgin primary forest. Therefore due to such a long delay it is likely that many extinction events would occur before this takes place (Barlow *et al* 2007). Forest protection and restoration will need to focus on protecting primary forests, connecting fragmented forest and reducing edge effects that threaten already vulnerable species. There are positive changes occurring, but with an estimated 100 species being lost a day (CBD 2010), it is unknown whether sufficient mitigation can be implemented fast enough to protect the majority of flora and fauna.

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